



Orbiting Carbon Observatory-3 OCO-3 Mission

Watching The Earth Breathe... Mapping CO₂ From Space

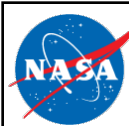
OCO-3 on the ISS: Development of a Science Utilization Plan

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Ralph R Basilio, and the OCO-3 Team

with contributions from
Robert R Nelson & Robert Rosenberg, JPL

Jet Propulsion Lab/California Institute of Technology

2019 ISS Research&Development Conference
Atlanta, GA 2019

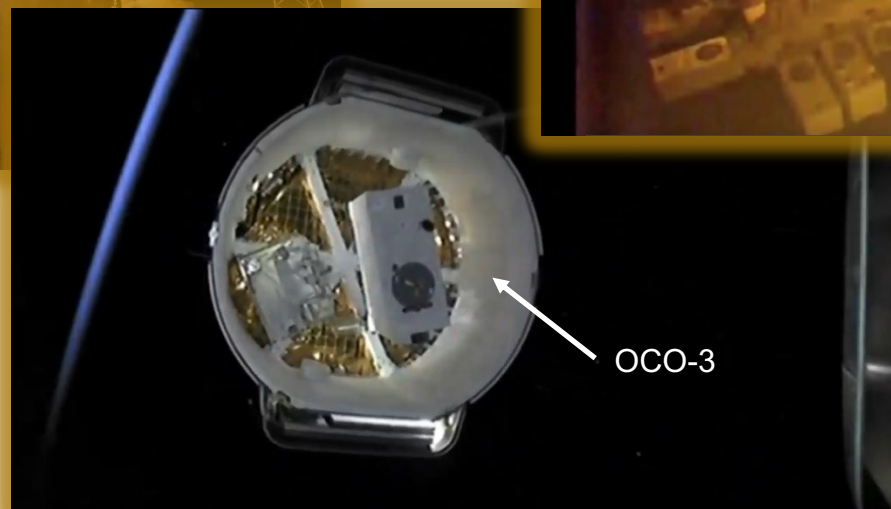


Successful OCO-3 Launch: 04 May 2019

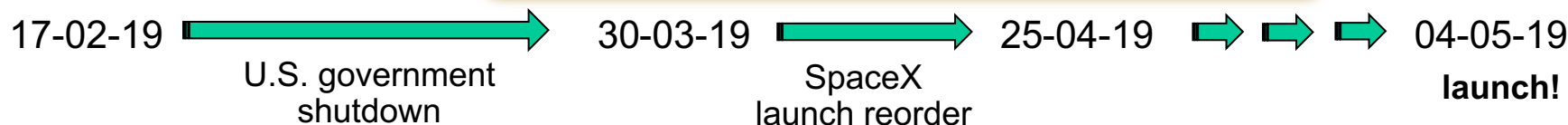


4 May: SpaceX 17 Launch
Falcon 9/Dragon Capsule

10 May: ISS Robotic Arm Installation



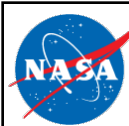
of Dragon
Capsule from
Falcon 9 Stage 2
after separation





Outline

- OCO-3 history – a movie
- Mission goals and mission status
- What's new about OCO-3 and being on the International Space Station
- Using the pointing system to take snapshot area maps/observing plan
- First Light results
- Data release schedule



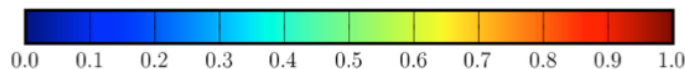
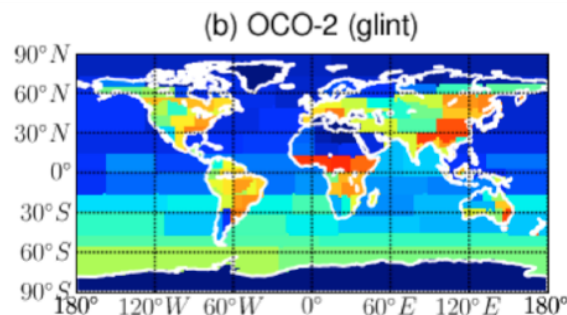
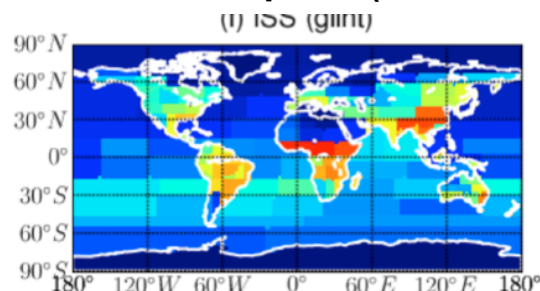
OCO-3 history – a movie



OCO-3 Science Overview

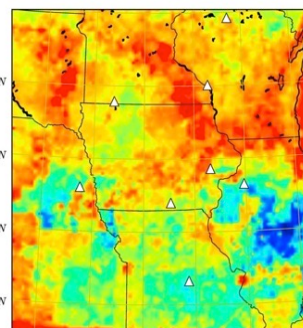
Continued Global CO₂

Global Flux Estimates: OCO-2
and OCO-3 impacts (simulated)



Flux error improvement for January
Palmer et al., 2011

Unique Science Opportunities with OCO-3



Midwest Carbon Flux
From Schuh et al., 2013

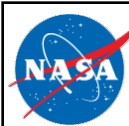
Terrestrial Carbon Cycle

Process studies enabled by
measurements at all sunlit
hours, including SIF. ISS will
contain complementary
instrumentation.



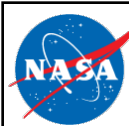
Snapshot Maps

Enabled by enhanced
target mode using pointing
mirror assembly

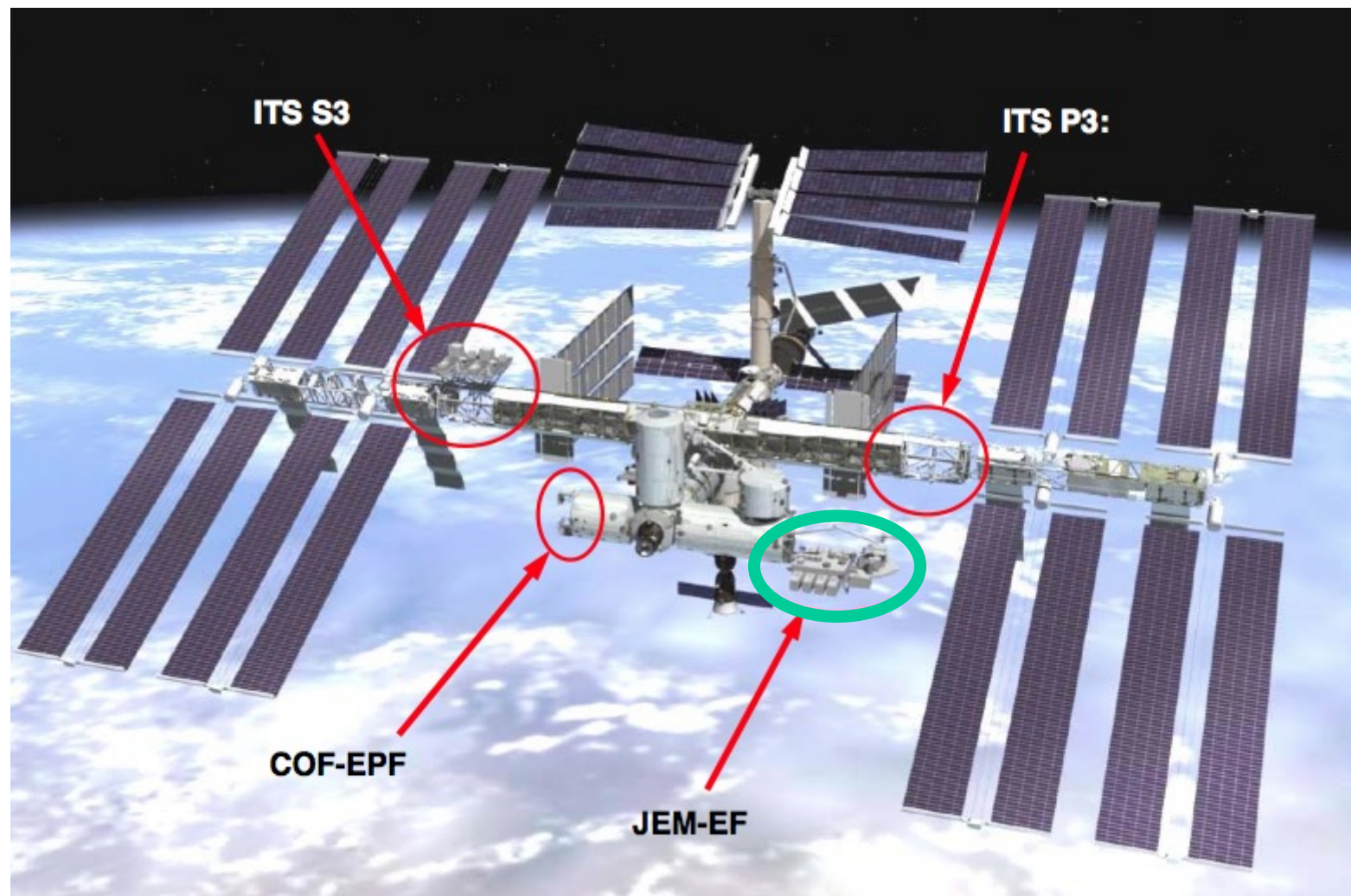


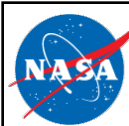
Key Dates and Activities

- Successful launch **04 May 2019** on a Space-X Falcon-9
- JEM installation completed **10 May 2019**; OCO-3 powered up; **all systems nominal**
- **In-orbit checkout (IOC)** – **currently ongoing, until early August**
- After IOC, the first 90 days focused on calibration and preparing to **release L1b (Oct/Nov 2019)**
- Next 90 days we focus on **L2 for release (Feb/Mar 2020)**
- We will use the NASA Data Center (GES-DISC) to release some small, preliminary datasets throughout this time period



ISS External Payload





OCO-2 vs OCO-3 – What's Different About the ISS?

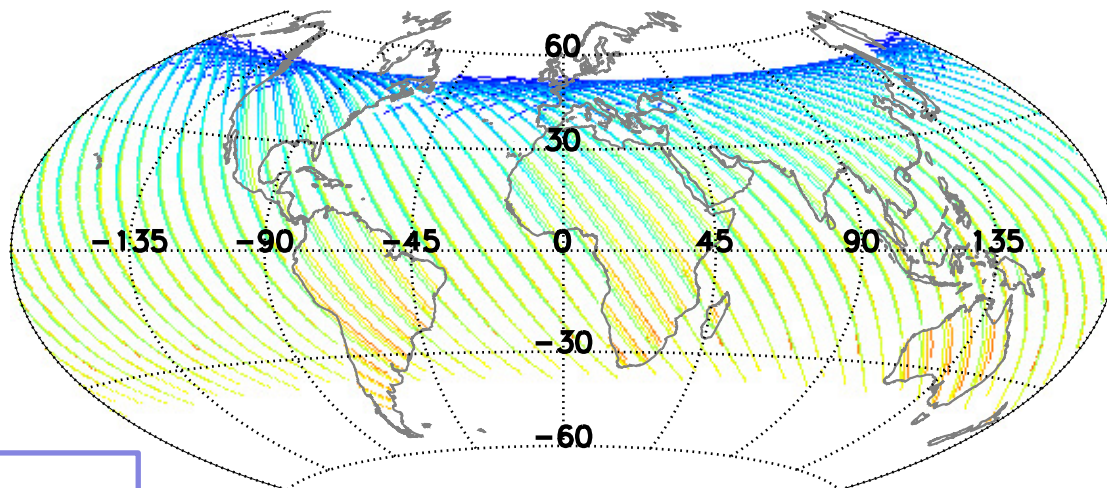
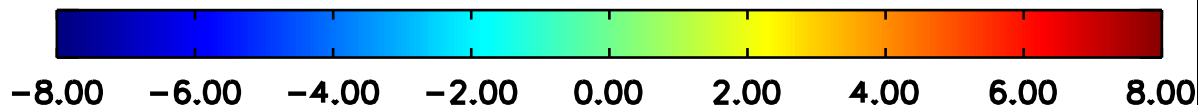
- **OCO-2 is in a sun synchronous orbit like most earth observing missions**
 - All measurements ~1330h local time; orbit tracks repeat every 233 orbits (or 16 days)
 - Pointing achieved by movements of the spacecraft
- **OCO-3 on the International Space Station**
 - Precessing orbit means that **local time** of measurements **is a little earlier each day; non-repeating orbits; day-by-day shift** in **latitudinal coverage** (with sunlight/time of day changes)
 - Pointing achieved with a 2-axis pointing system
 - Can use pointing system for up to 100 locations per day (chosen to manage the planning process and with consideration of lifetime of pointing system)
- **OCO-3 is the spare flight instrument of OCO-2**
 - identical detector hardware; modifications to OCO-3 include a different aperture size to compensate for the lower ISS orbit, and the addition of internal and external context cameras as well as a polarizer
 - individual ground footprints are comparable: **1.6x2.2 km², 13 km swath width**



Sampling from the ISS is Changing Constantly



Time from local solar noon (hours)



From the ISS

- We observe from 52°N to 52°S
- At a wide range of times of day
- Both of these vary from day to day!!

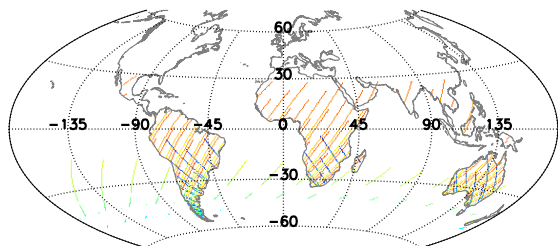
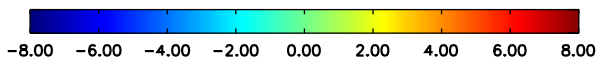
Sampling over 10 days

Figure provided by Tommy Taylor, CSU

Progression of Sampling Across Hours of the Day and Latitude

Days 60-69

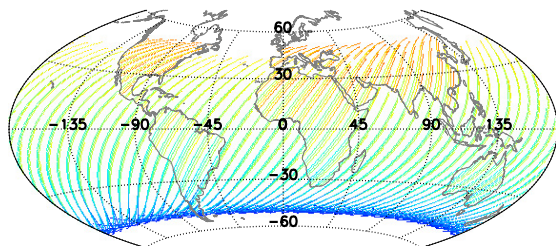
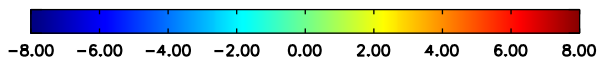
Time from local solar noon (hours)



NumSound= 4214

Days 70-79

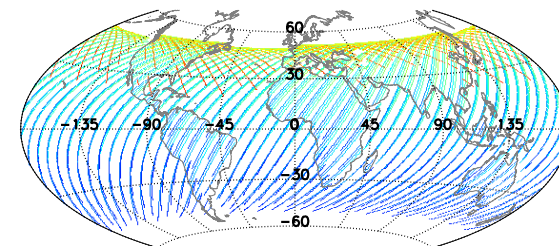
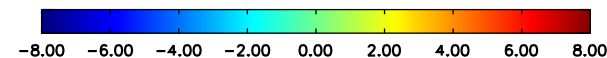
Time from local solar noon (hours)



NumSound= 34235

Days 80-89

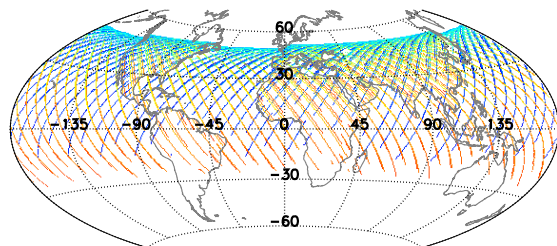
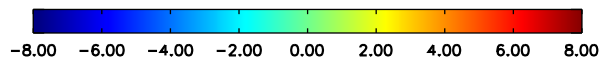
Time from local solar noon (hours)



NumSound= 38944

Days 90-99

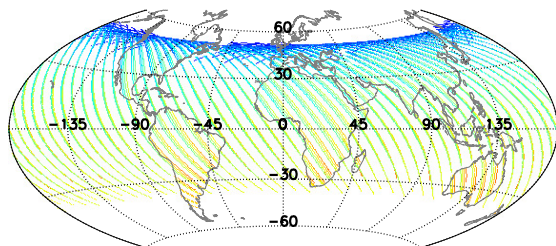
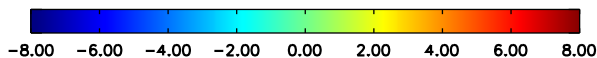
Time from local solar noon (hours)



NumSound= 39627

Days 100-109

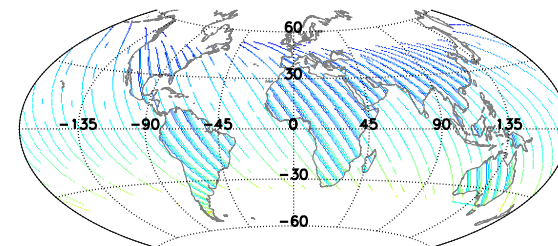
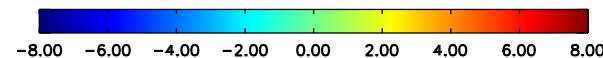
Time from local solar noon (hours)



NumSound= 34416

Days 110-119

Time from local solar noon (hours)



NumSound= 11945

Figures provided by Tommy Taylor, CSU

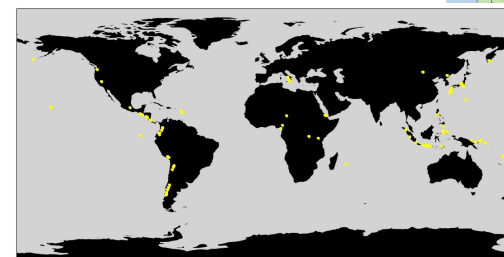
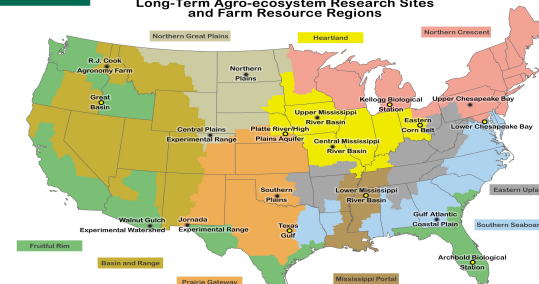
Science Inputs to Mission Planning

Snapshot Maps and Targets:

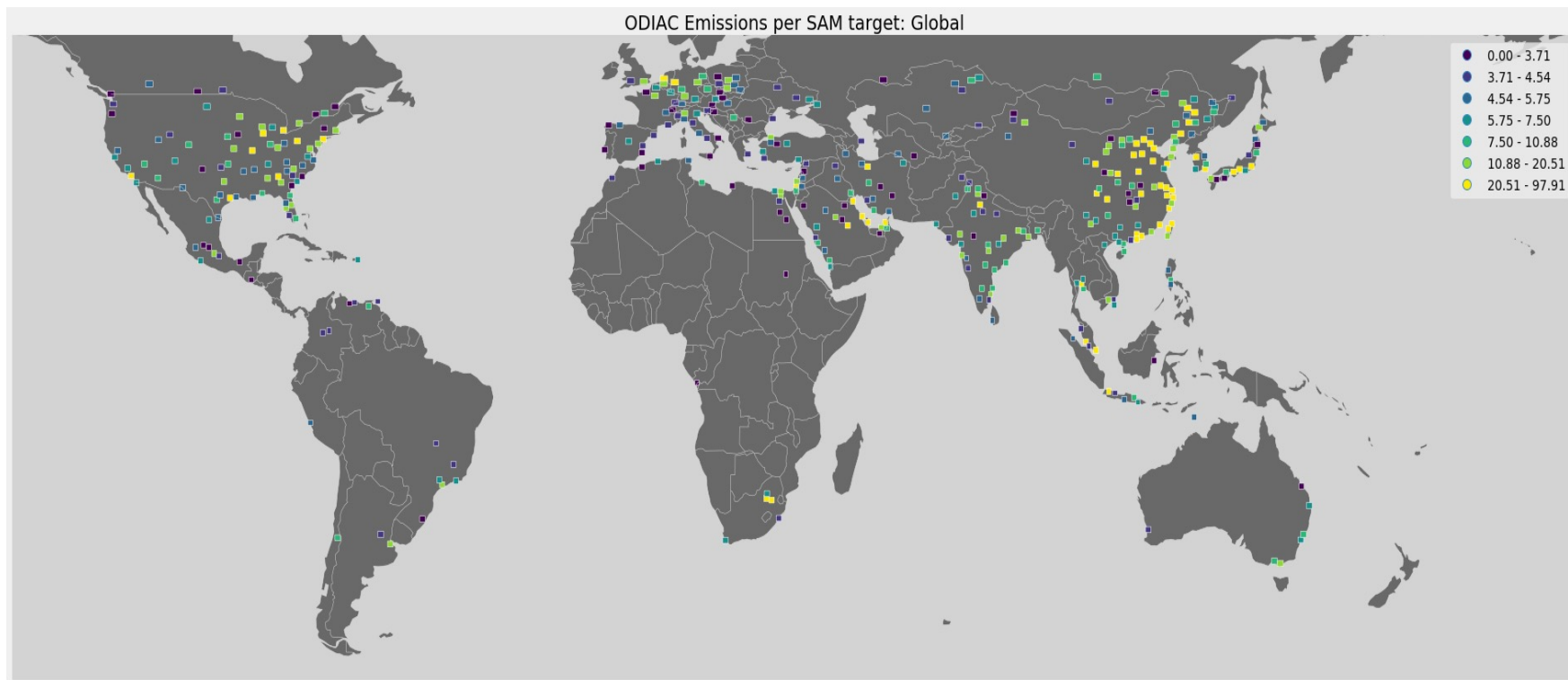
- **Calibration targets** (Radiometric calibration at pseudo-invariant desert playas, e.g. Railroad Valley)
- **XCO₂ validation targets** (TCCON/COCCON network sites)
- **Fossil fuel CO₂ emissions hotspots** (cities and powerplants)
- **Terrestrial ecology** (SIF-GPP relation over the day, multi-instrument constraint on terrestrial biosphere models)
- **Volcanoes** (quantifying degassing => predicting eruptions?)



Long-Term Agro-ecosystem Research Sites and Farm Resource Regions



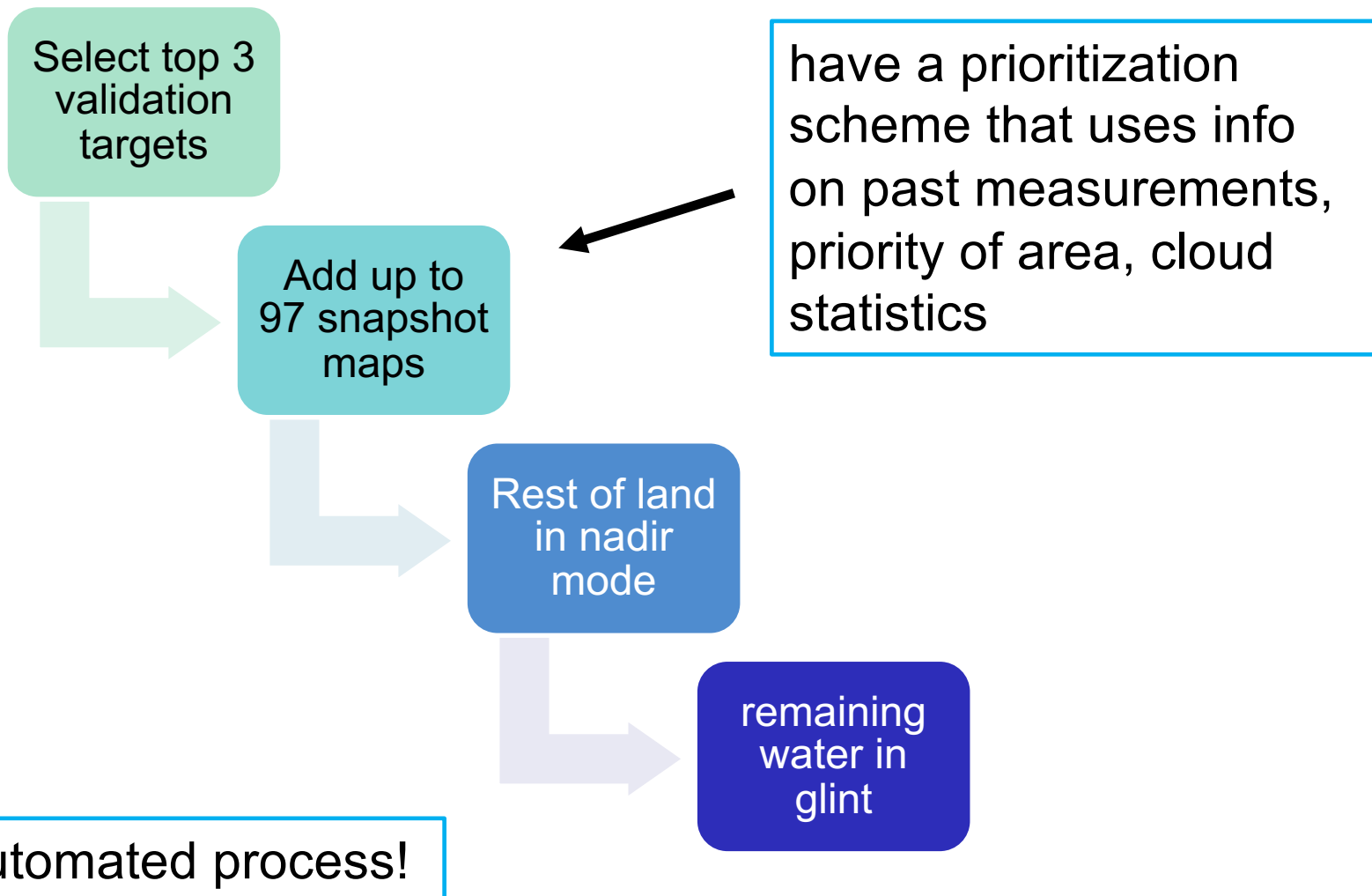
Selected High Emissions Intensity Locations for Sampling List



- initial list of SAMs, to be updated during the course of the mission
- special SAMs can be requested at oco3_sam_requests@jpl.nasa.gov
- target cloudy places more often to obtain sufficient coverage (using MODIS cloud climatologies)



Science Observation Planning Logic

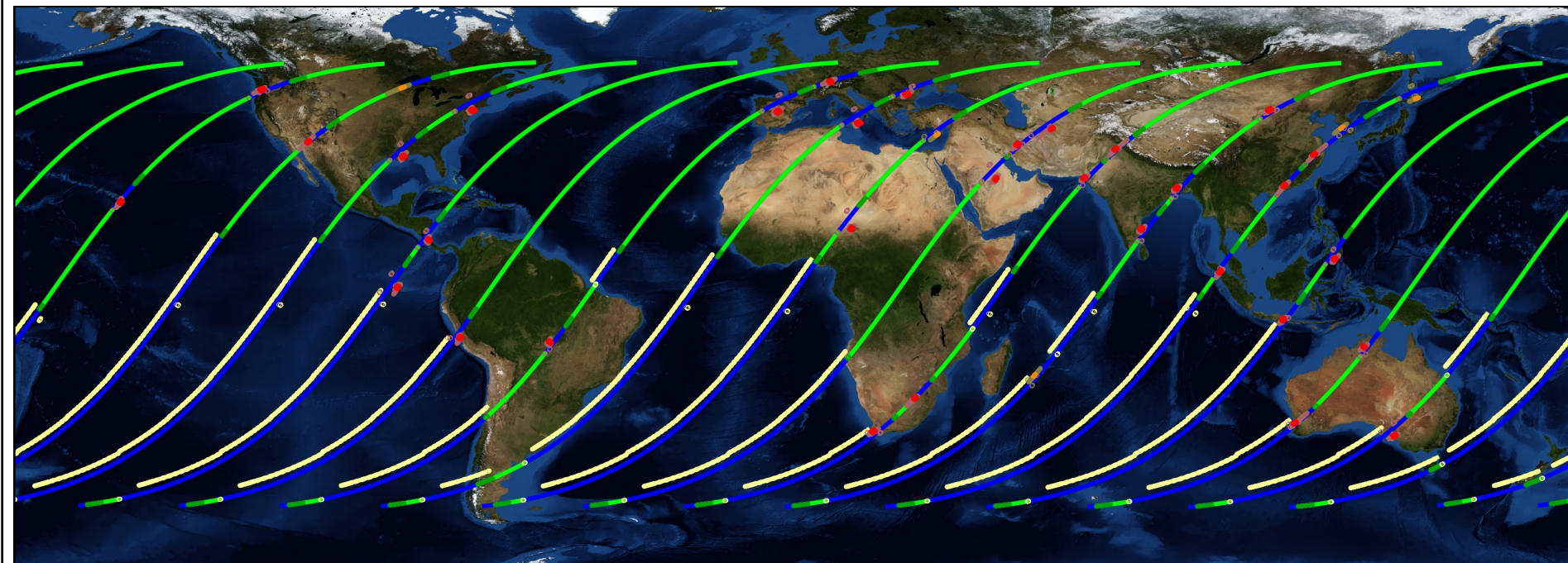




OCO-3 Science Observation Planning is Automated



Simulation: One day of OCO-3 Observations



Nadir
Glint
ISS track

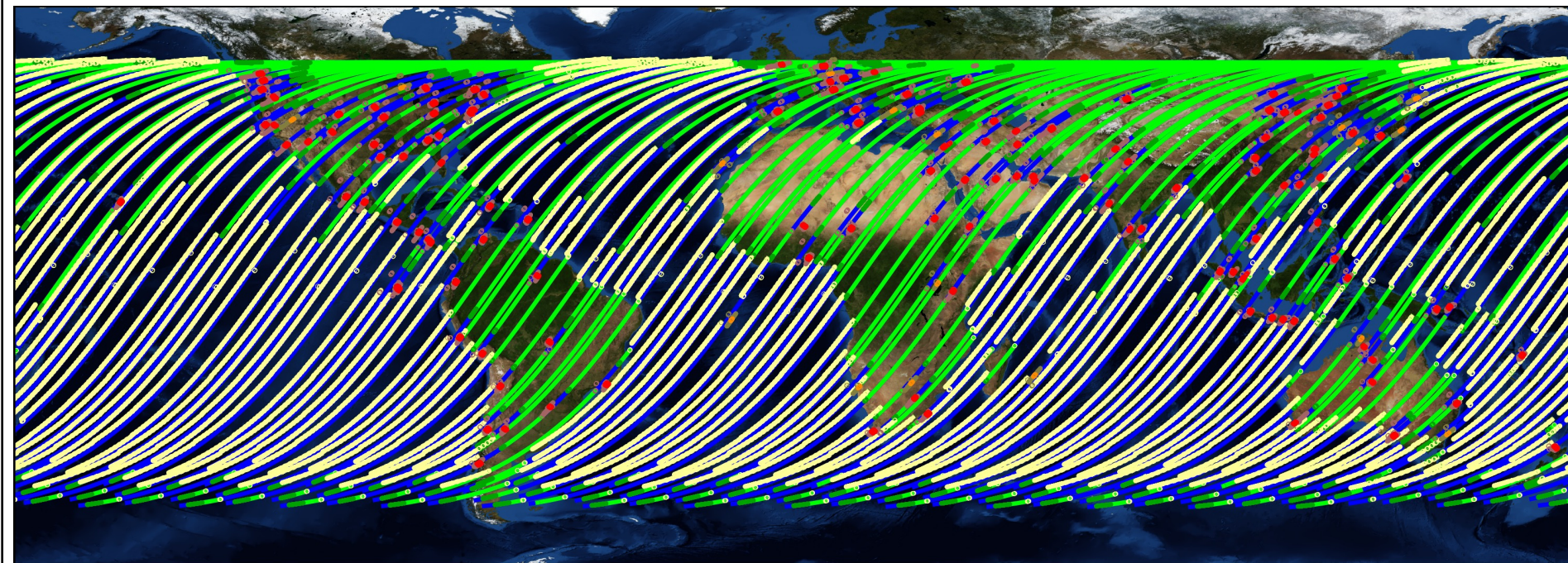
Validation target
City/Volcano/SIF



OCO-3 Science Observation Planning is Automated



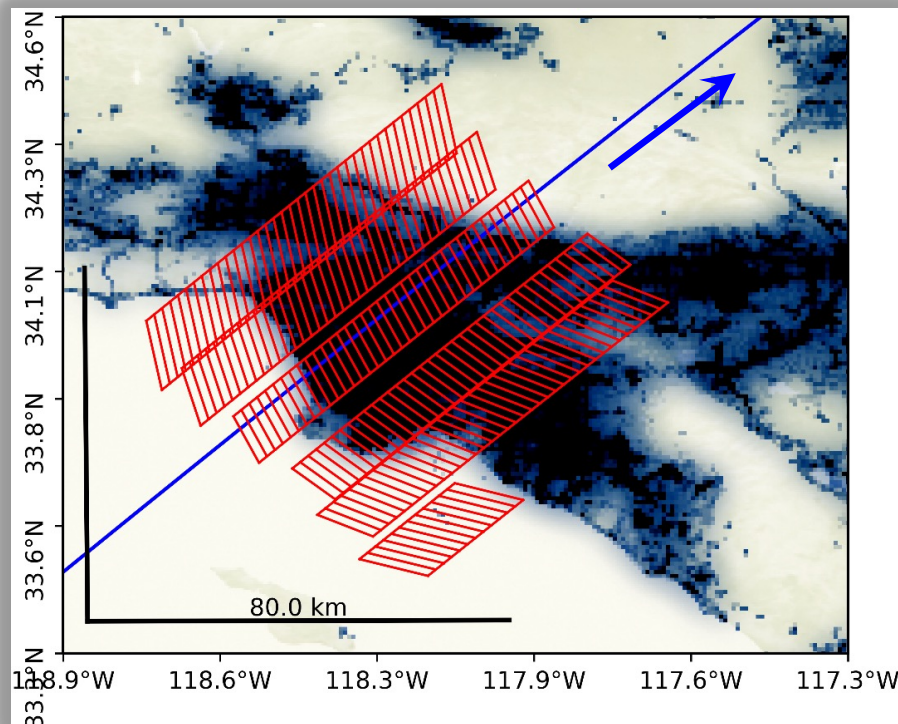
Simulation: Six days of OCO-3 Observations



Nadir
Glint
ISS track

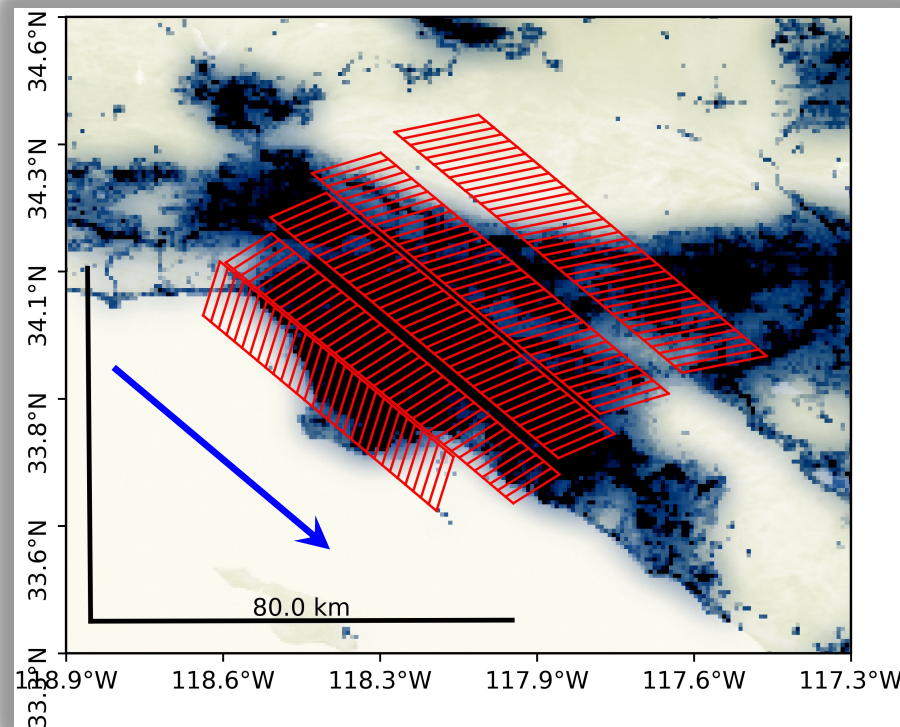
Validation target
City/Volcano/SIF

Snapshot Area Maps Cover 80x80 km²

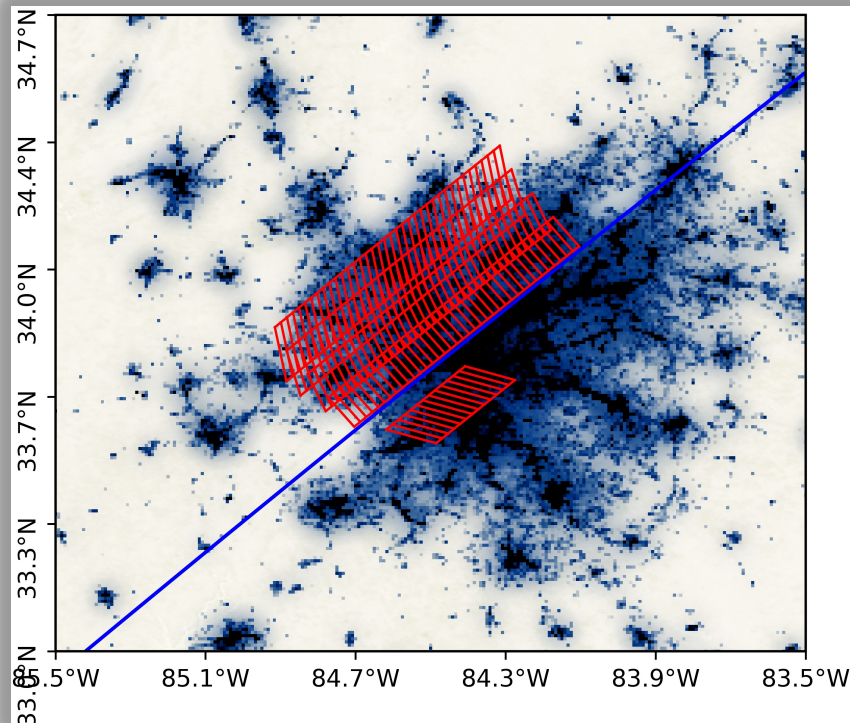


orientation of coverage depends on the ascending/descending node of the ISS

rotation of segments depends on the approach angle of the ISS and forward/rearward viewing geometry

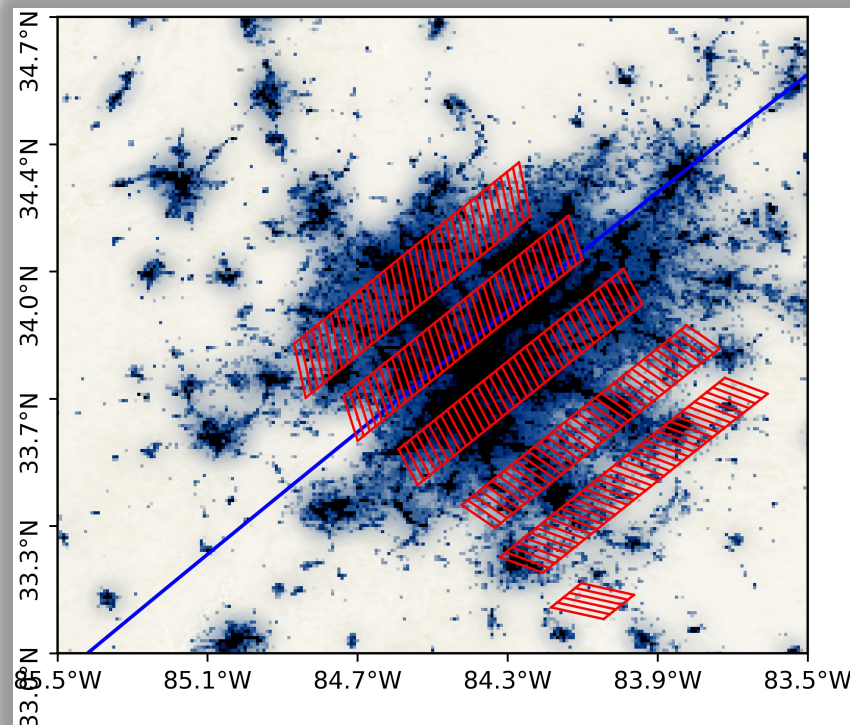


Snapshot Area Maps – Options



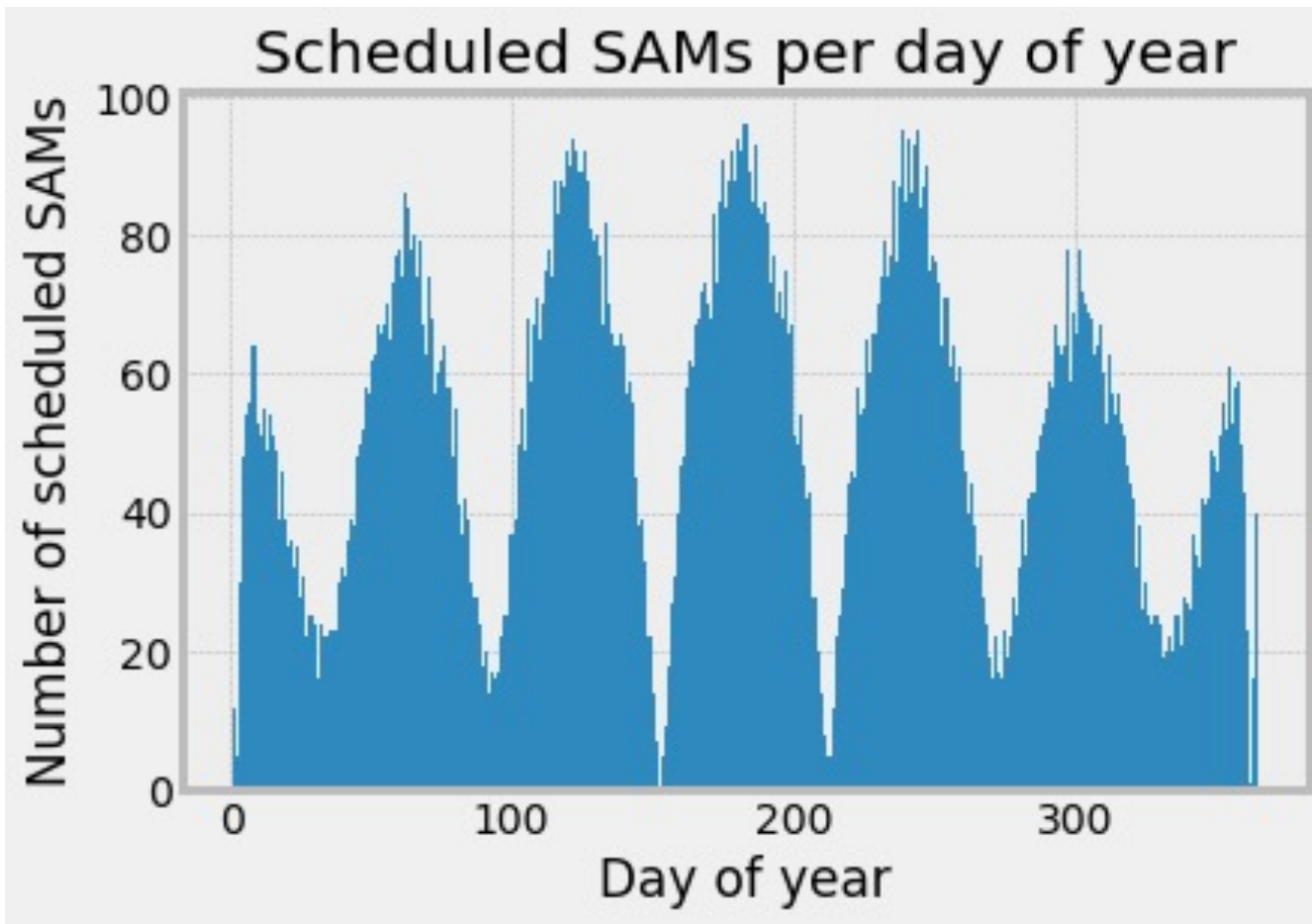
“squeezed” coverage: consecutive segments have spatial overlap

“stretched” coverage: consecutive segments separated by spatial gaps



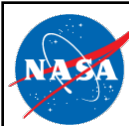


Annual Frequency of SAMs (2015 Simulation)



Dips

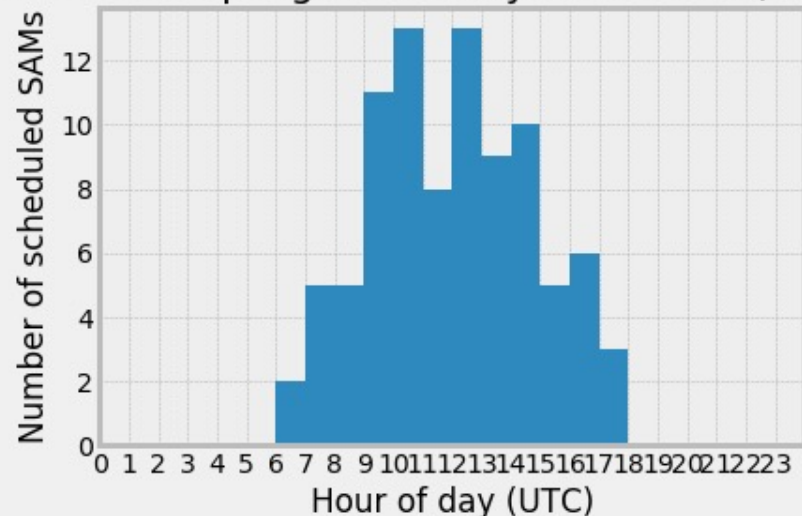
predominantly southern hemisphere observation. *i.e.*, northern hemisphere is in darkness



Paris Snapshot Area Maps Details (2015 Simulation)

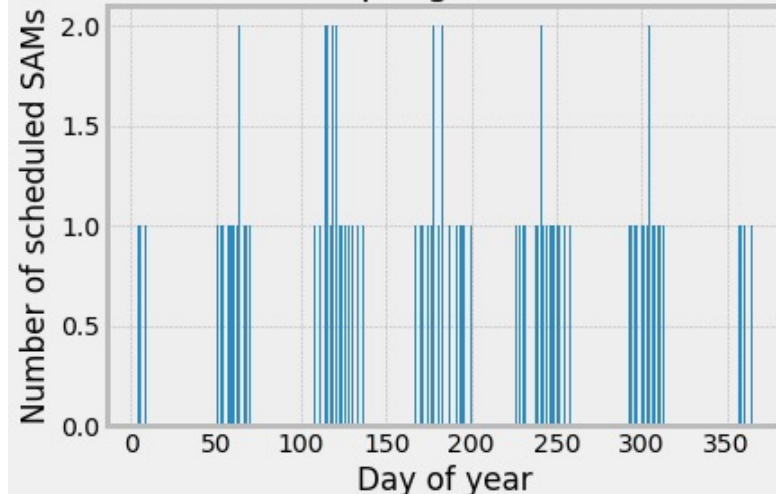


Diurnal sampling over one year for Paris, France

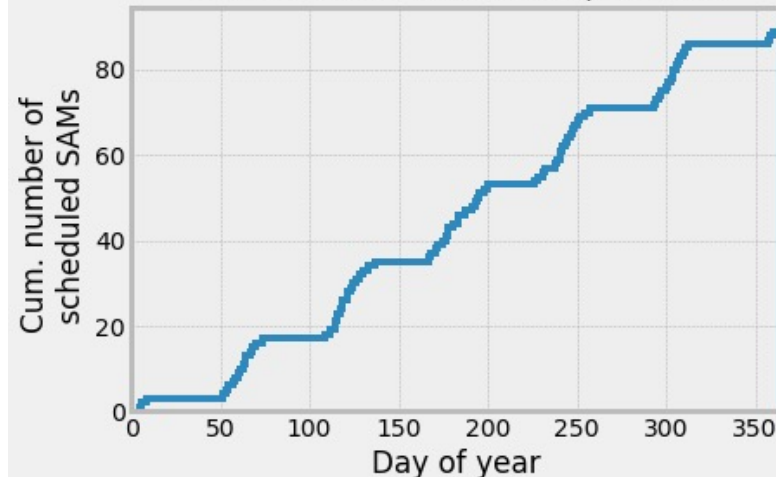


- observations from dawn to dusk
- occasionally 2 observations per day
- temporal gaps of up to 1 month
- cumulative ~100 observations/year

Sampling for Paris



Scheduled SAMs: Paris, France

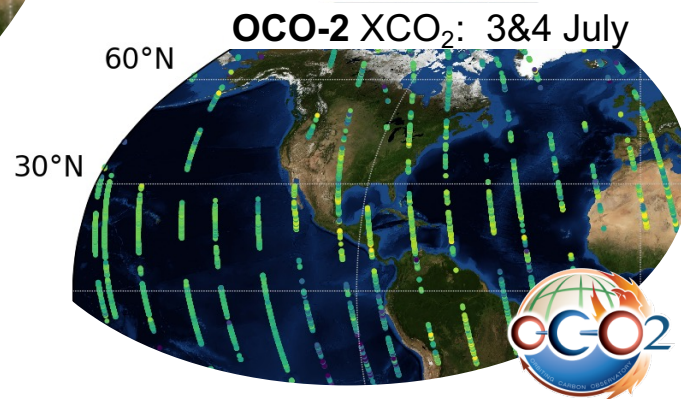
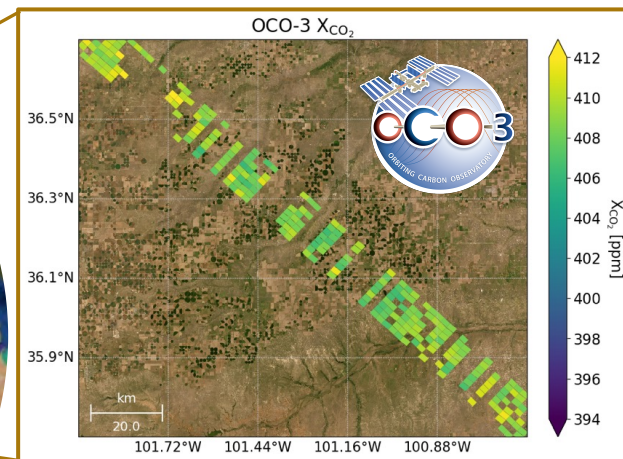
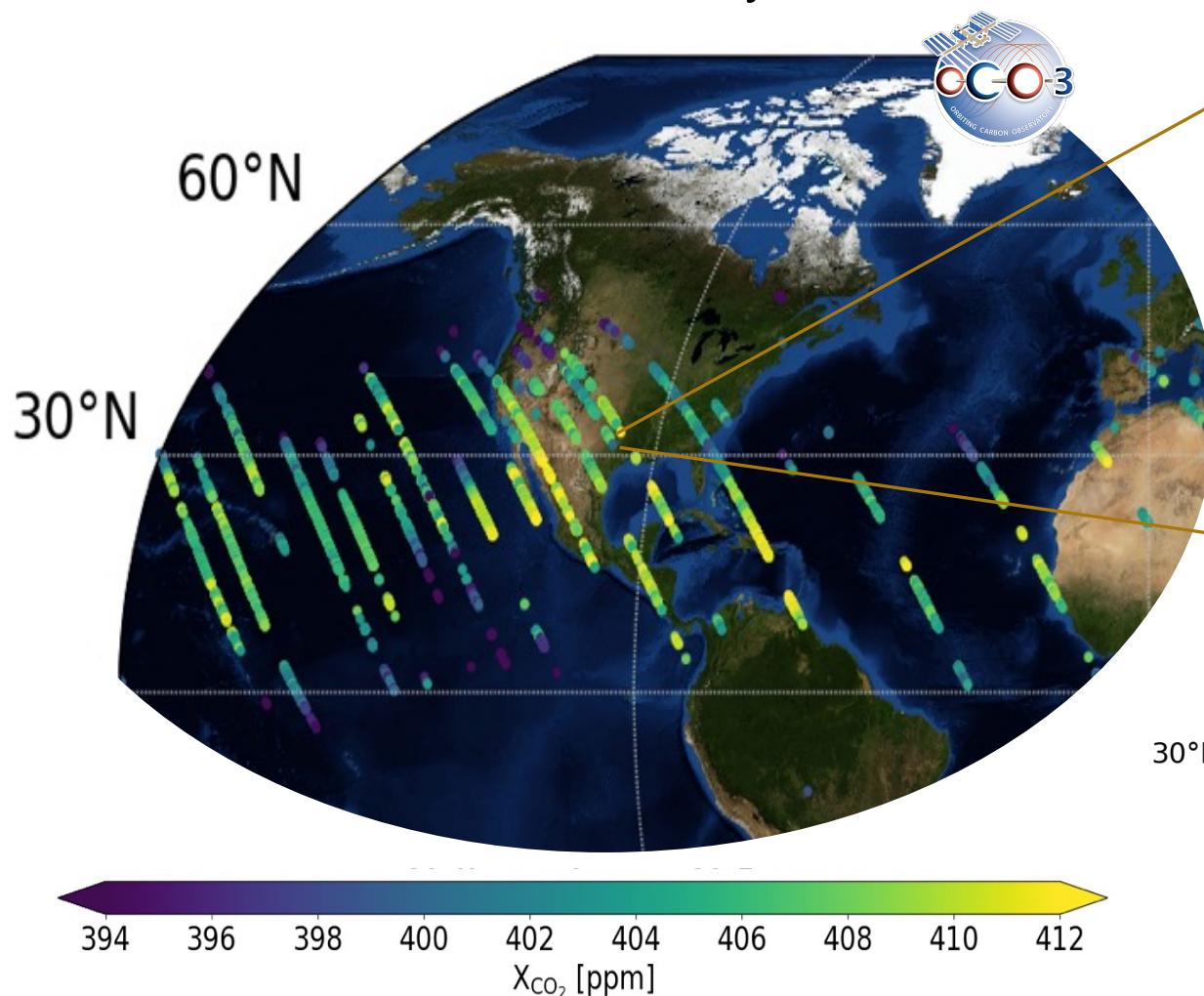


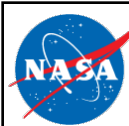
OCO-3 First Light Results: XCO₂



Data collected 25 June, 2&3 July 2019

Data produced by OCO-3 SDOS,
 graphics by Robert Nelson, JPL
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 U.S. Government sponsorship acknowledged.





OCO-3 First Light Results: Solar-Induced Fluorescence



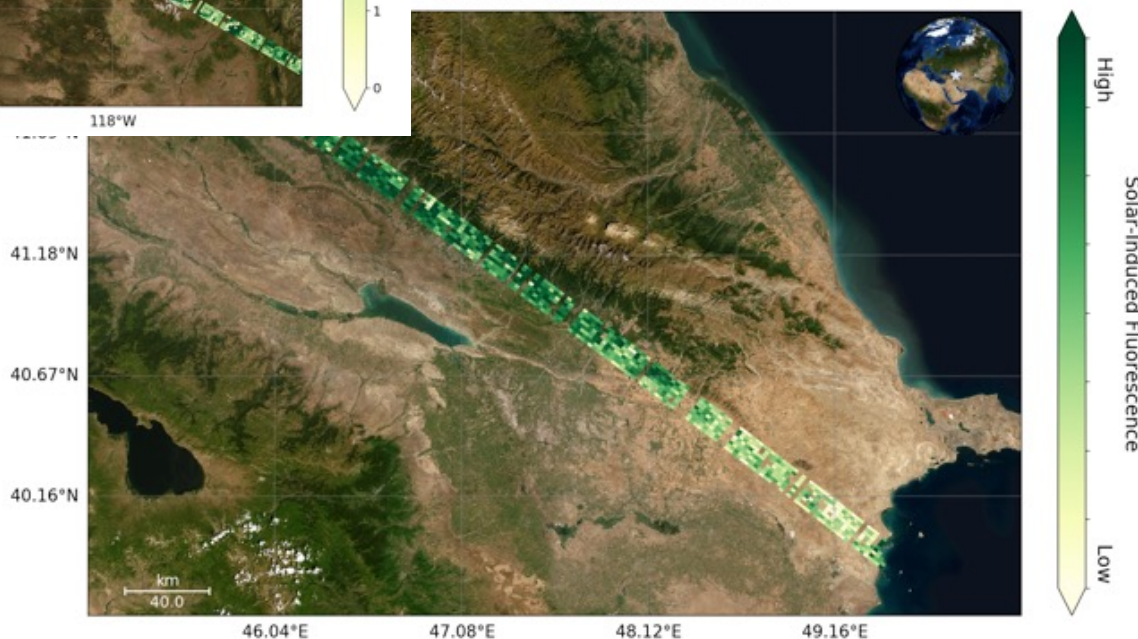
RetrievalResults/physical/757nm/sif_radiance_gbg



Data produced by OCO-3 SDOS,
graphics by Robert Nelson, JPL
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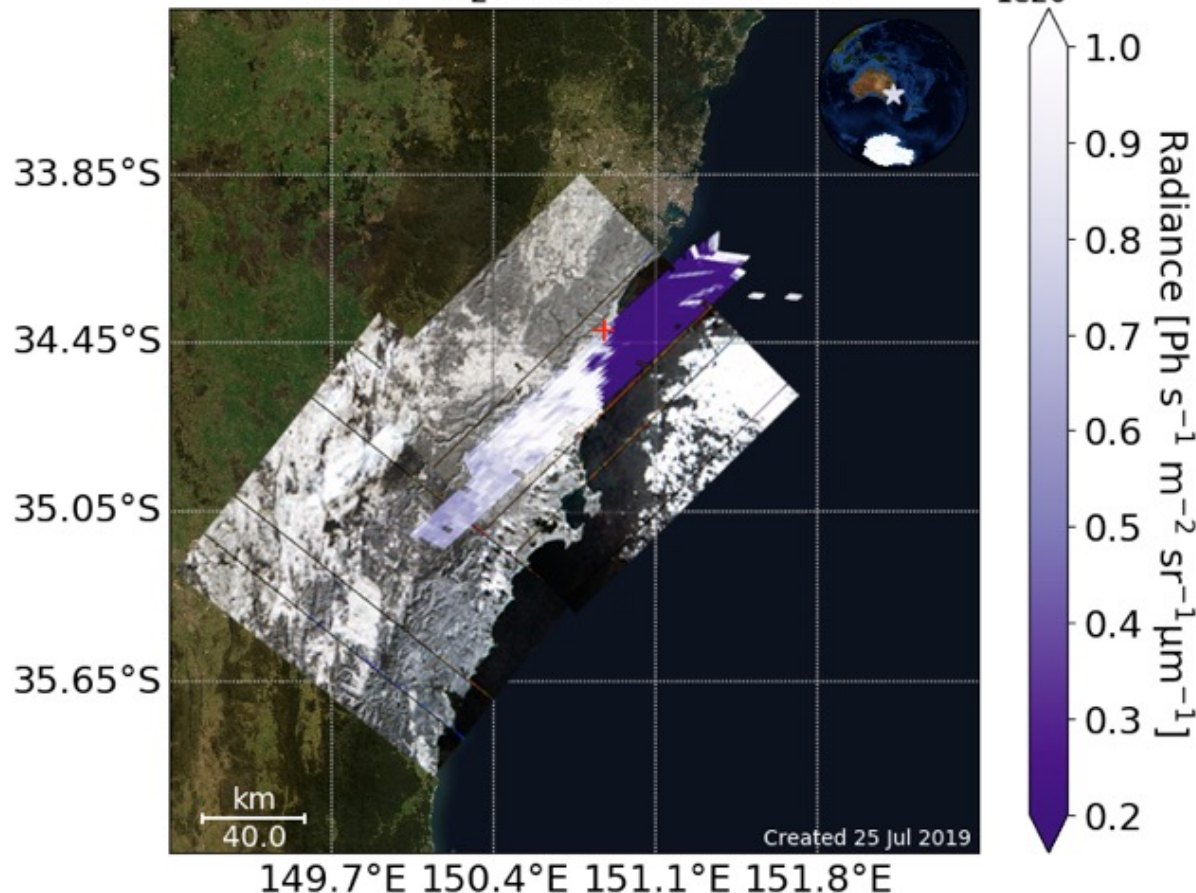
Solar-Induced Fluorescence (SIF) is a measure of plant photosynthetic activity and plant health, which can be related to carbon uptake; **deeper greens** indicate **higher activity**.

Solar-Induced Fluorescence



OCO-3 First Light Results: Target Observations

OCO-3 O₂ A-Band Radiance



Example of O₂ A Band
radiance from a **Target
Mode Observation** over
Wollongong, Australia.

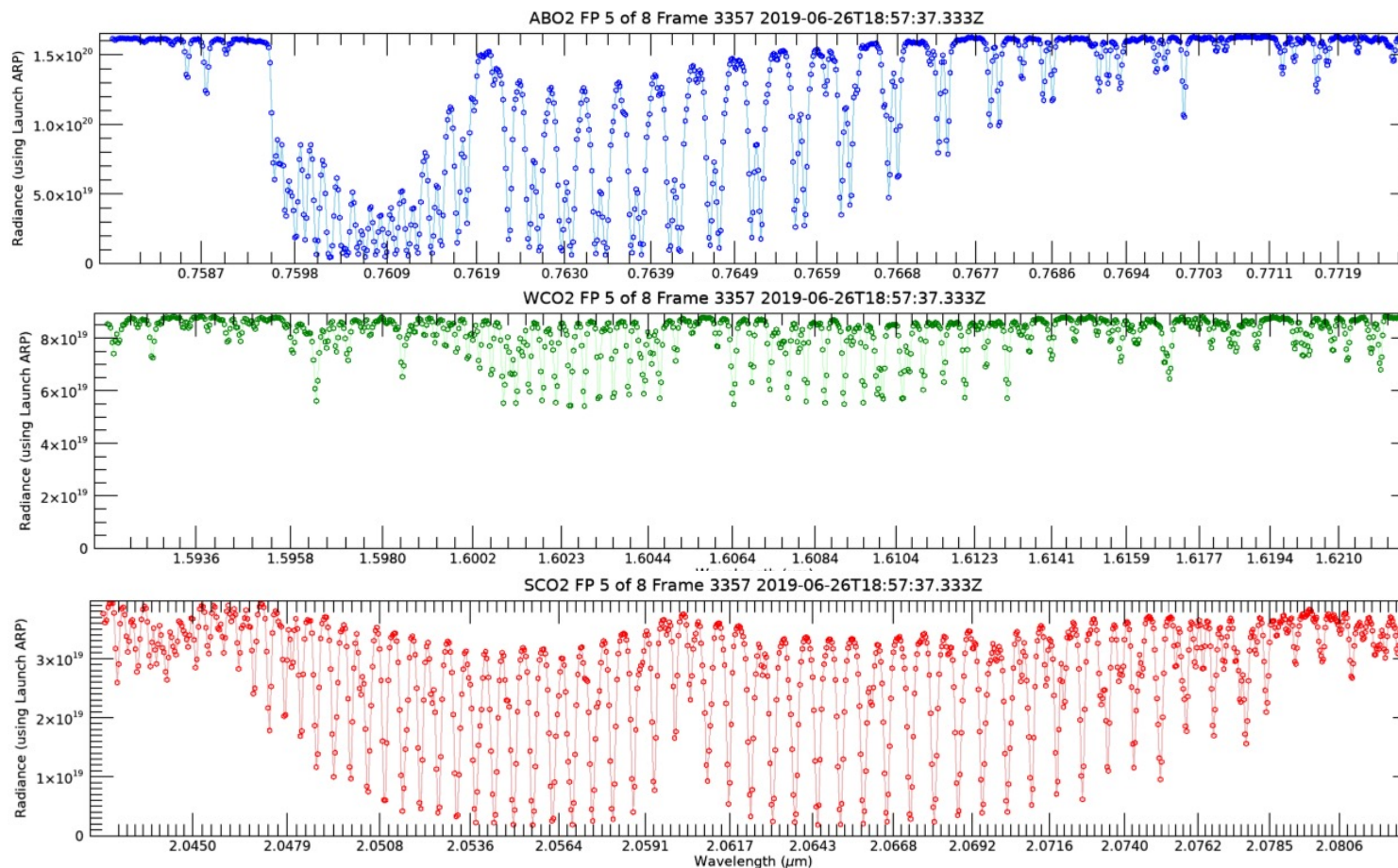
the gray-scale background
images are taken by OCO-3's
External Context Camera.

the + indicates the **centroid
location** of the target position.

Data produced by OCO-3 SDOS, graphics by Robert Nelson, JPL
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OCO-3 First Light Results: Radiance Spectra



O₂ A Band

weak
CO₂ Band

strong
CO₂ Band

OCO-3 first-light spectra show a significantly smaller amount of bad&dead pixels compared to OCO-2

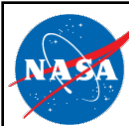
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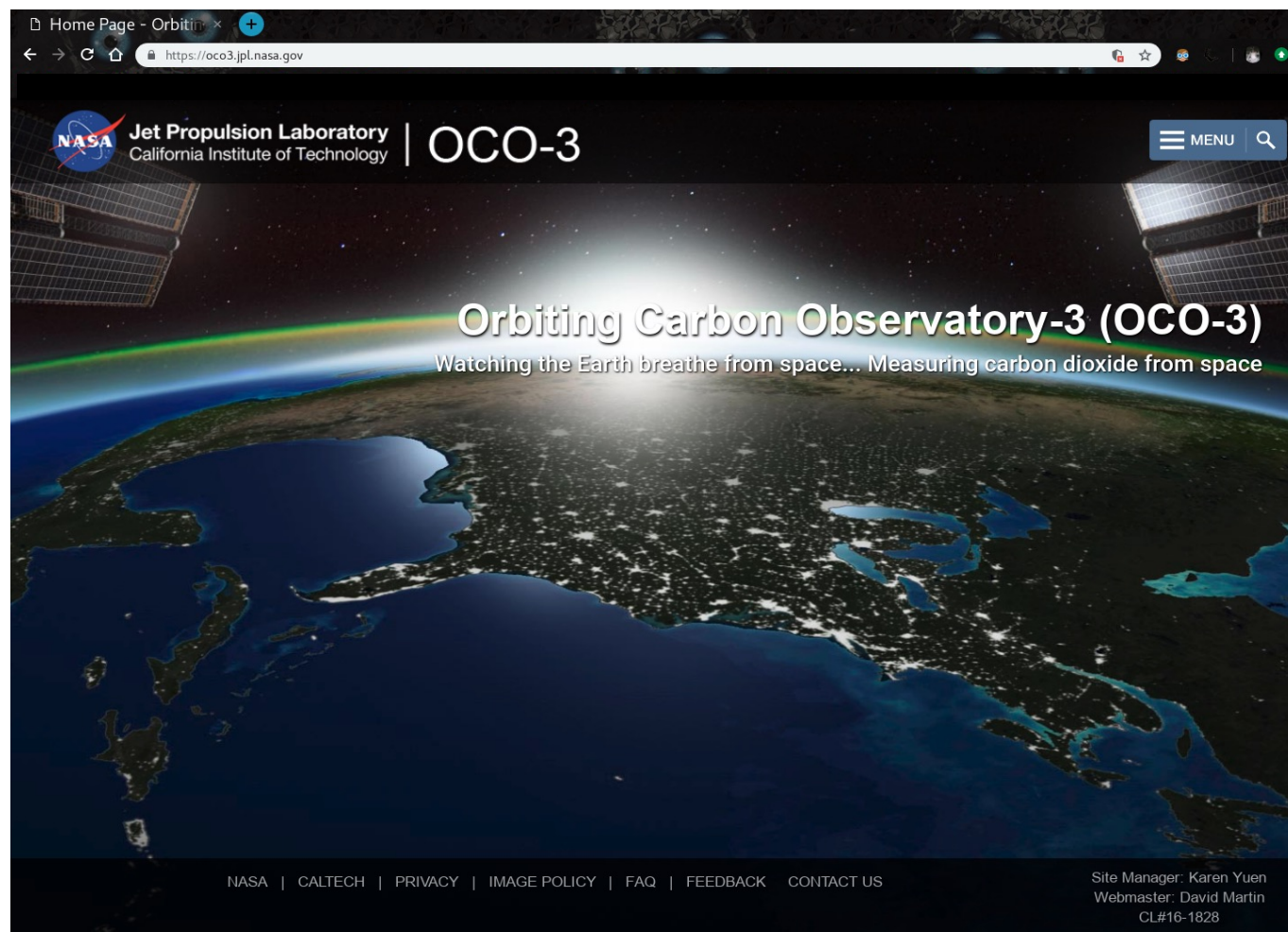
OCO-3 Mission Timeline – What's Next?



- **Complete** In-Orbit Checkout (early August) and enter routine science observations
- **Pass** Post-Launch Assessment Review (9 August) 🍷
- **Release** Level-1 data products, *e.g.*, radiances (Oct/Nov 2019)
- **Release** Level-2 data products, *e.g.*, XCO₂, SIF (Feb/Mar 2020)
- **Continue** science observations and improve data products until end-of-mission (nominally 3 years, *e.g.*, 2022)



web portal: oco3.jpl.nasa.gov



use portal for: mission updates, data availability, **request special observation targets**, ...



Summary



- OCO-3 **measures and map carbon dioxide** from space in great detail improving our understanding of the interaction between carbon and climate.
- OCO-3 demonstrates a new "**snapshot**" **mode** capable of mapping local differences in CO₂ from space for the first time.
- OCO-3 is the first instrument to measure **Solar-Induced Fluorescence** (an indicator of photosynthesis efficiency) in high definition **from dawn to dusk** from space.
- OCO-3 **continues the remote sensing CO₂ record** with data that can be used in combination with ongoing OCO-2 measurements.

thank you

